

ROYAL SOCIETY REPORT ON THE WEST INDIAN ERUPTIONS.¹

THE Soufrière mountain forms the northern extremity of St. Vincent, and its general form at once suggests a comparison with Vesuvius. It is a simple cone without lateral or parasitic craters. The one at its summit is surrounded on the north side by the remains of a gigantic crater ring, which has the same relation to the present crater as Somma has to Vesuvius. On the north-east lip of the main crater there is a smaller one known as the New Crater, as it is believed to have originated in the eruption of 1812. It is only one-third of a mile in diameter. It is doubtful whether the New Crater was active during the late eruption, and there can be no doubt that it was from the principal crater, or "Old Crater," that the materials mostly were emitted. Deep valleys, often with precipitous sides, have been cut in the slopes of the mountain, especially on its southern side, and it is in these—and particularly in the Wallibu, Rozeau and Rabaca Dry River—that the greater part of the ejecta of the recent eruption have collected.

Premonitory Signs of Activity.

The eruption of May, 1902, though sudden in its outburst and disastrous in its effects, was far from unexpected. In the north of St. Vincent there were two settlements of the Aboriginal Caribs, and these had been so startled by the frequent violent earthquakes, that in February of last year they were considering the advisability of deserting the district. But the first signs of actual volcanic activity were on Tuesday, May 6. The inhabitants of the leeward side were fortunate in having a clear view of the crater, and warned by the outbursts of steam they fled to Chateaubelair, and other places along the coast-line to the south, so that few lives were lost in this quarter. But, on the windward side, the summit of the mountain, as is frequently the case, was wrapped in cloud. Here, at the base of the mountain, there is an extensive stretch of flat land, known as the Carib country, on which were situated some of the largest and richest estates in the island, with a dense population, mostly black or coloured. So little alarm was felt here, that even on the morning of Wednesday, May 7, when the leeward side was practically deserted, sugar-making was in progress on several estates, and all the operations of tropical agriculture were being conducted as usual. From Kingstown, telephonic messages were sent to Georgetown, which is not far from the base of the hill, stating that the Soufrière was in eruption, but they appear to have occasioned little anxiety. And when, about mid-day on Wednesday, the danger was too obvious to be overlooked, the Rabaca Dry River, and some of the streams on the windward side, usually dry except after rains, were running boiling hot, and could not be crossed. Many fugitives in this way found their escape cut off. It was here that the loss of life was greatest, which, though many escaped, is estimated to have amounted to 2000, including about a dozen white men—the overseers of the plantations. The exact number will never be known, as many were entombed in the ashes where they fell.

Progress of the Eruption.

About mid-day on May 6 the first signs of the eruption were observed by those dwelling on the south-western side of the mountain. At 2.40 that afternoon there was a considerable explosion, and a large cloud of steam ascended into the air. By 5 o'clock a red glare was visible in the steam cloud on the summit. Activity continued during the evening, and at midnight there was a great outburst, and red flames were noticed on the lip of the crater. Next morning from Chateaubelair a splendid view could be obtained of gigantic mushroom-shaped clouds rising to a great height in the air—estimated at 30,000 feet—and drifting away before the north-east trade wind. As the day advanced the eruption increased in violence; by 10.30 a.m. enormous clouds of vapour were being emitted with loud noises, accompanied by much lightning. It is remarkable that at that time the inhabitants of the windward side were still in doubt about the reality of the eruption, since they mistook the dark cloud covering the mountain for a thunder cloud. The mountain was now in a state of continuous activity, and from Chateaubelair it could be seen that the materials were mostly discharged from the old or principal crater. Vast clouds of steam, showers of

dark matter (probably mud), and of stones, could be seen projected from it, partly on the leeward, but mostly on the windward side. At mid-day the slopes of the mountain were still green, and the rich mantle of tropical vegetation had not yet been destroyed. A thin layer of fine ash had fallen over the lower ground, only sufficient to give the leaves a greyish colour. The enormous columns of vapour continued to ascend from the crater, with frequent violent outbursts, projecting showers of stones and mud.

About this time it was noticed that steam was rising from some of the valleys on the south side of the hill, and this increased until at 12.50 the whole mountain was suddenly enveloped in a dense cloud of vapour. Just before this the rivers Wallibu and Rabaca had been seen rushing down in raging floods of boiling water. It is most probable that these phenomena were due to the escape of the crater lake, which was driven over the lower or south lip of the crater between 12 o'clock and 1 o'clock on the Wednesday afternoon, and poured down the valleys to the sea. So far as we know there were no mud lavas, in the ordinary sense, flowing down these valleys, but only a tremendous rush of boiling water, which left no traces which we could recognise when we visited the district.

By 1 o'clock the roaring of the volcano was tremendous. Showers of stones were being projected both to windward and to leeward. The enormous columns of steam continued to ascend from the crater. The lightnings were terrific, and after the large outbursts, which took place every few minutes, volumes of vapour might be seen covering the whole area. Hitherto the eruption had been of a type with which geologists are familiar, and the destruction done was confined to the higher parts of the mountain in the close vicinity of the crater.

But about 2 o'clock—to quote the words of an eye-witness (Mr. T. M. McDonald, of Richmond Vale Estate)—"there was a rumbling and a large black outburst with showers of stones, all to windward, and enormously increased activity over the whole area. A terrific huge reddish and purplish curtain advanced to and over Richmond Estate." This was the strange black cloud which, laden with hot dust, swept with terrific velocity down the mountain-side, burying the country in hot sand, suffocating and burning all living creatures in its path, and devouring the rich vegetation of the hill with one burning blast.

The Hot Gases and Dust.

On the leeward coast few were overtaken by the black cloud, as the inhabitants had fled and taken refuge in the villages south of Chateaubelair. Those who were caught were killed or badly burned. One boat was near Richmond at the time the blast swept down. The occupants describe the heat as fearful. Hot sand rained into the boat, and the sea around was hissing with its heat. The darkness was so complete that a man could not see his hand. They saved their lives by diving into the water; when they returned to the surface the air was suffocating, but they continued to dive again and again, and, when at their last gasp, they found that the air cleared, and they could breathe again. This occupied only a few minutes—probably much less in reality than it appeared to them. One man was too exhausted to continue diving; he clung to the gunwale of the boat, and the tops of his ears were severely scorched.

On the windward side of the island an uninterrupted view of the progress of the eruption could not be obtained, owing to the veil of cloud which obscured the summit. By mid-day on Wednesday even the most sceptical were convinced that the Soufrière was in eruption, and that the noises heard continuously were not due to a thunderstorm. Before mid-day there had been very heavy rain-showers, and it was noticed that the rain-drops carried down fine particles of ash. Work ceased on the plantations, and those labourers who still remained endeavoured to escape to Georgetown or shut themselves up in their houses. By 2 o'clock fine ashes, with occasional larger stones, were falling steadily, but, as yet, little damage had been done, and no one had been injured. Then came the climax of the eruption, and those who were in the open air saw a dense black cloud rolling with terrific velocity down the mountain. They took refuge in their houses and in the plantation works, where they crowded together in such numbers that in one small room 87 were killed. The cloud was seen to roll down upon the sea, and was described to us as flashing with lightning, especially when it touched the water. All state that it was intensely hot, smelt strongly of sulphur, and was suffocating. They felt as if something was compressing their throats, and as if there was no

¹ Abridged from a preliminary report by Dr. Tempest Anderson and Dr. J. S. Flett, just published in the *Proceedings* of the Royal Society, vol. lxx. pp. 423-445.

air to breathe. There was no fire in the ordinary sense of the word, only the air was itself intensely hot and was charged with hot dust. The suffocating cloud only lasted a few minutes. Those who survived this ordeal mostly escaped, though many died within a few hours from shock, or from the severity of their injuries. In some cases a few survived, entirely or almost entirely uninjured, in a room in which many others died. Most of those who escaped had shut themselves up in the rum cellars or in substantially built houses, and had firmly closed all doors and windows. By the time the hot blast had reached the coast the sand it contained was no longer incandescent, and though still at a very high temperature it did not set fire to wood or burn the clothes of those exposed to it. The burns on the survivors were chiefly on the outer aspect of the arms and legs, and on the faces, and confined to parts not protected by their clothes.

The Rain of Dust.

Complete darkness now covered the whole north end of St. Vincent—a darkness more intense than any the inhabitants had ever before experienced. The fugitives had to creep along the roads or feel their way along the roadsides. The roaring of the mountain was terrible—a long, drawn-out, continuous sound resembling the roar of a gigantic animal in great pain. Fine ash and sand rained down over the whole country with occasional showers of large stones. Some of these were so hot as to set fire to the trash roofs of huts in the south-end of Georgetown, at a distance of 7 miles from the crater. In Kingstown, 12 miles from the Soufrière, the ash was at first moist, but afterwards dry. It had a strong sulphurous smell, and pattered on the roofs like a heavy shower of tropical rain. Around the volcano the earth shook and trembled continuously, and the motion was described to us as undulating rather than resembling the sharp shock of an earthquake. Only in one or two cases were the walls of houses injured. What was taking place on the summit of the mountain no one can tell, but all who passed that night in the vicinity of the Soufrière agree that there was one black suffocating cloud, and only one. In all probability the eruption had reassumed the ordinary phase, and the showers of ash and stones were produced by violent upward explosions of steam. By half-past 5 o'clock the ash was falling in Barbadoes, 100 miles to the eastward, whither it had been carried by the upper currents of air in a direction opposite to that of the trade winds. In St. Vincent the darkness lessened slightly before nightfall, but the rain of dust and the noises lasted until early in the ensuing morning.

When day broke it was seen that in St. Vincent, and even in Barbadoes, everything was covered with fine grey ash resembling a fall of snow. The dust had penetrated into the interior of the houses, where it lay in a thin film on walls and furniture. In Kingstown there were stones as large as a hen's egg; in Georgetown and Chateaubelair some had fallen as much as 1 foot in diameter. Little damage, however, appears to have been done to growing crops, except in the north-end of the island. In fact, many believe that the sulphurous ash had insecticidal properties, and benefited the vegetation. From Chateaubelair it could be seen that the volcano was still emitting puffs of slaty-coloured steam, and showers of fine dust were falling on the leeward side of the mountain. For several days these discharges of vapours continued, but a new phenomenon now attracted more attention. The ravines which furrow the south side of the mountain were found to be discharging clouds of vapour, and this gave rise to reports of fissures having opened on the flanks of the Soufrière, of subsidiary eruptions arising from these fissures, and of streams of lava flowing down the valleys. As a matter of fact, they were really due to the action of water flowing through the hot sand, which in some places had almost obliterated the old stream courses, as will be explained more fully later on. By May 15 the volcanic activity had apparently subsided, and the mountain remained clear and unclouded. The explosions of steam in the valleys continued and are probably still going on.

The state of quiescence continued until Sunday, May 18. Confidence was being restored, and the inhabitants of those districts near the mountain which had not suffered severely were returning to their homes. On the windward side the work of burying the bodies had been completed and things were resuming their normal course. But about 8 o'clock that evening an ominous sound was heard from the crater. Its nature was at once recognised and struck the black population with terror. The

noises were as loud as those of the first eruption, and the lightning was very vivid. On the leeward side complete darkness prevailed, and ashes and sand fell freely for some hours. In Georgetown the fall of ashes was quite inconsiderable, not exceeding a thin film on the roofs of the houses. Gradually the noises lessened, the darkness lifted, and the moon appeared again. No lives were lost and practically no damage was done, but exactly what happened on those parts of the mountain nearest the crater it is, in the circumstances, impossible to say. This second eruption was the last which proceeded from the main crater. Clouds of steam were sometimes seen gently rising for some days later, but nothing of the nature of a volcanic outburst has since taken place.

Products of the Eruption.

We arrived at Kingstown on Tuesday, June 10, and proceeded at once to Chateaubelair, where Mr. Jas. E. Richards, of Kingstown, kindly placed a house at our disposal. The geological products of this eruption proved to be of very simple character. The Soufrière and the surrounding country were covered with a layer of ashes mostly in the form of fine dark-coloured sand, but mixed with spongy bombs of various sizes and many ejected blocks composed of fragments of the old rocks of the hill. Lapilli and scoria are there in plenty, as is obvious where the heavy rains have washed away the finer material, but the greater part of the ejecta consists of fine sand which, when dry, is hot and yellowish-grey in colour, but when wet becomes almost black. This sand, as has already been noted by many observers, contains plagioclase feldspar, hypersthene, augite, magnetite and fragments of glass, and represents a fairly well-crystallised hypersthene-andesite magma which has been blown to powder by the expansion of occluded steam.

The coarser material is mostly a slaggy andesite with crystals of plagioclase and pyroxene. There is little pumice, though we obtained a few fragments which floated on water and contained but few crystals visible to the naked eye. The larger bombs are often black, highly lustrous and glassy when broken across. Some were seen at Wallibu (4 miles from the crater) 3 feet in diameter. The ejected blocks consist of weathered andesites and andesitic tuffs such as can be seen in the walls of the crater. They are very numerous, and some are more than 5 feet across. In addition to these, fine-grained dark green banded rocks occur, which appear to be baked and indurated sediments, probably the mud from the bottom of the crater lake, or the finer beds intercalated in the older volcanic series. Another type of ejected block which is very common in some parts of the hill is a coarse-grained aggregate of feldspar, hornblende (brown under the microscope), and perhaps olivine. It is not vesicular and contains little or no glass, being apparently holocrystalline. These rocks are very friable, and the crystals are loosely aggregated together. They seemed to us to be comparable to the sandinites of the Eifel and many other modern volcanic districts. They are certainly quite unlike true plutonic diorites, both in their structure and in the character of their minerals.

It may be noted that none of these rocks are characteristic of this eruption, but all can be found among the older materials of the hill. The hardened, baked sediments were well known to the Caribs, who have long used them for the manufacture of their finer stone implements. The feldspar-hornblende blocks were found by us among the older rocks, and in some places even as rounded masses enveloped in the old lavas. Some of the fresher bombs in the river beds and the seashore can hardly be distinguished from those which were the product of this eruption, though undoubtedly of much older date.

The conclusion was forced upon our minds that immense quantities of hot sand had rushed down the hill into these valleys in an avalanche which carried with it a terrific blast, and piled the ashes deep in the sheltered ravines, at the same time sweeping everything off the exposed ridges which lay between. The rain of volcanic material, which lasted for hours after the hot blast had passed, then covered the surface of the country with a final sheeting of fine dust and scoriæ.

Effects produced by the Hot Blast.

When we ascended the Soufrière, the evidence of the passage of a hot blast laden with sand was overwhelmingly clear. The various stages of its action, and its varying intensity at different spots, are most easily observed on the windward side, where the country is more flat and open, and there are fewer ravines and

spurs to modify the course of its operations than in the Wallibu Valley.

The track to the summit passes across the Rabaca Dry Valley near the shore, then turns upwards through the sugar-cane fields of Rabaca and Lot 14. These were covered with 3 or 4 feet of sand and scoriæ, the trees all bare, their leaves stripped by the falling cinders; but few branches were broken, and no trees had been uprooted or cast down. The woodwork of the houses was unburnt, though the roofs of some of the verandahs, and of the labourers' huts, had collapsed from the weight of ashes that had fallen on them. Many people were killed on these estates. The survivors described to us how the dark cloud had rolled down from the mountain, and how hot and suffocating the air had been when it enveloped them. But it was evident that the velocity of the blast was not above that of an ordinary gale, and the dust it carried, though hot, was not incandescent.

At Lot 14 it was seen that many trees had their limbs twisted off and broken, and some of the negroes' houses had taken fire (probably mostly from hot falling bombs). The blast was more violent here, but not hot enough to set fire to the woodwork or char the green wood of the standing timber.

On the flat ground above the plantation buildings (at an elevation of about 1000 feet), a further stage of devastation was encountered. The fields were here swept bare, the trees broken down, though not as a rule uprooted, their smaller branches swept away; a deep layer of black sand covered the crops of sugar-cane. The blast was here a violent gale.

A little further up the effects of the blast were remarkable. Enormous trees had been uprooted and cast down. Their leaves and finer branches, of course, had disappeared. In every case the fallen trunks pointed directly away from the crater. Even the great cotton-trees, 10 feet or more in diameter, were broken off or uprooted. The smaller trees had in a few cases been swept away like straws. The larger were merely cast down, and lay side by side, their tops directed down the valley, their roots towards the summit of the mountain. Most were charred, some deeply, but, as the wood was green, only the smaller branches had been consumed. The effect was like that produced by a violent hurricane, only more complete, for many of these trees had withstood the hurricane which ruined St. Vincent in 1898. At the lower limit of this region some curious effects of the hot sand blast could be seen. Where any branches or trunks were still standing, they invariably showed themselves to be burnt and eroded on one side—that next the crater—the wood having been charred and the charred material removed by the action of a hot sand blast. On the side away from the crater, the original bark was still left, unburnt, but dry and peeling off; that is, there had been no erosion on the sheltered or lee side of the stems. The wood was too green to take fire, but the sand had been sufficiently hot to char the surfaces which were exposed to it.

Further up the hill—that is to say, above the 1500-foot level, there was little left of the rich tropical vegetation which had covered it from summit to base. Blackened remains of tree-trunks were to be seen, overturned or broken off near the ground, and buried in dark sand. The highest parts of the mountain are as bare and desolate a scene as could be imagined. The ash is 5 to 12 feet deep, and though full of large blocks and spongy bombs, is mostly so fine that when thoroughly wet it becomes a fine mud, very tenacious and slippery, in which one sinks to the knee. In it there is a good deal of burnt timber, utterly blackened and converted into charcoal. Everything has been mown down, and at the same time the intense heat has consumed all the smaller fragments and charred the larger. There is nothing to show what was the velocity of the blast when it left the crater. After a couple of miles it was that of a hurricane or tornado. The limit between the zone of uprooted trees and that of trees still standing, but broken and much damaged, is surprisingly sharp. At 4 miles from the crater the blast was travelling at 20 to 40 miles an hour, and rapidly slowing down. This agrees with the evidence of an eye-witness who saw it when it reached the sea near Chateaubelair. It came over the water with a wave before it, but it did not overturn the small boats which lay in its course.

Another peculiar feature of this blast is the manner in which its course was modified by irregularities in the configuration of the ground over which it passed. To the north of the crater stands the encircling crater wall, already referred to as the Somra. There can be no doubt that a black cloud descended

over this side of the mountain, though here the devastation is comparatively slight, and it is inferred that the high intervening ridge overlooking the crater served as a rampart and helped to protect the country behind it from the effects of the blast. The southern lip of the crater, on the other hand, is the lower, and the avalanche of hot sand seems to have poured over this lip almost like a fluid. Down the deep open valley between the Soufrière and the Morne Garu Mountain it rushed, ever following the steepest descent. It clung to the valley bottoms and coursed along them in a manner which somewhat recalls a raging torrent in a river. The streams in these valleys after descending the first part of the hill turn sharply at a right angle towards the coast, deflected by the opposing mass of the Morne Garu. The hot blast mostly followed these valleys, and in them it piled up enormous deposits of sand, but part of it swept up the shoulders of Morne Garu, and tore up the heavy timber which was growing there. The direction in which the fallen trunks point shows that the blast was split into two parts—one taking the east and one the west side of the mountain, rushing upwards obliquely from below. The mountain protected the country behind, and the line of demarcation between the burnt and the green forest almost corresponds with the dividing ridge. The south side is green; the north side towards the Soufrière is devastated and burnt.

Geological Modifications.

Apart from the changes which have taken place within the crater, and the deposits of ash which have formed in the river valleys, and on the surface of the hill, the only other important geological modification of the country has been the disappearance of a narrow strip of coast along the leeward side of the island. Near the mouth of the Wallibu and from thence northward to Morne Ronde, the sea has encroached on the land for perhaps 200 yards. Below Wallibu plantation there stood a village of labourers' huts on a low flat beach with a bluff behind. Here the sea now washes the foot of a cliff some 30 feet high. This cliff consists of soft tufts covered with several feet of new hot ashes, and is in an unstable condition, as masses are constantly falling down from its face. In this way a new beach is now forming in front of it. It is agreed by those who knew the district before the eruption that not only has the old beach disappeared, which carried the village and the public road, but that part of the bluff behind has also subsided. We were informed by Mr. T. M. McDonald, who is intimately acquainted with this coastline, that similar subsidences had also taken place, though on a much smaller scale, at several places further north. There is no evidence elsewhere of any changes of level of land and sea. The tide-marks on the rocks and the landing-stages at the villages enabled us to ascertain that the level of high-water was at any rate within a few inches of what it had been before. It was clear that the alterations in the coast-line were due to local subsidence of the foreshores, and that they had mostly affected loose and ill-consolidated deposits, such as beach gravels and the fans of alluvium which had formed at the mouths of the streams. The submarine slopes on the leeward side of St. Vincent are very steep, averaging about 1 in 4. Within half a mile of the shore the depth is often more than 100 fathoms.

It seems most probable that owing to the concussions and earthquakes produced by the explosions, some of the less coherent accumulations on these steep slopes slipped bodily into the deep. On this supposition most of the facts would be explained, but at the same time it is possible that at Wallibu the inner margin of the depressed tract may be a fault line. It has a very straight trend, and it is a curious fact that this shore was formerly known as Hot Waters. This might indicate the existence of a fissure up which hot springs were rising.

Comparison of the Soufrière with Mont Pelée.

When we arrived at Martinique, we had the pleasure of meeting Prof. Lacroix, the head of the French Scientific Commission, which had spent some time in making a preliminary survey of Mont Pelée, and the north-end of the island, and from him we obtained much valuable information regarding the sequence of events and the geological consequences of the eruptions in that quarter. It was our intention to make merely such reconnaissances as would enable us in a general way to ascertain the points of difference and of similarity between the outburst of Mont Pelée and that of the Soufrière, and to see what light the phenomena in Martinique threw on the events which had happened in St. Vincent.

Both volcanoes are of the same type, simple cones with a large vent near the summit and without parasitic craters. They are both deeply scored with ravines, and on their south-west sides there is a broad valley—occupied at Martinique by St. Pierre City, at St. Vincent by the Wallibu. It is in these valleys that the destruction has been most pronounced. In both, the recent eruptions have been characterised by paroxysmal discharges of incandescent ashes, and a complete absence of lava streams.

In St. Vincent, however, the mass of material ejected has been much greater, and a considerably larger area of country has been devastated than in Martinique. That the loss of life was not so large can be accounted for by the absence of a populous city at the foot of the mountain. Had the city of St. Pierre been planted at the mouth of the Wallibu, there can be no doubt it would have been equally completely destroyed.

On Mont Pelée, we understand that a fissure has opened on the south side of the mountain between the summit and St. Pierre, from which the blast was emitted which overwhelmed the city. But on the Soufrière the old orifices have been made use of. The eruption of Pelée began with the flow of mud lavas, but none such were seen in St. Vincent. On the other hand, the hot blast which swept down on the doomed city was essentially similar to that which we have described as having taken place at the Soufrière. Both eruptions produced principally hot sand and dust, with a small proportion of bombs and ejected blocks.

Observations of an Eruption of Mont Pelée.

We were fortunate in having an opportunity to witness one of the more important eruptions of Mont Pelée before we left Martinique, and this enabled us to see how far the actual phenomena corresponded with the ideas we had been led to form from an inspection of the effects of the earlier outbursts. On July 9 we were in a small sloop of 10 tons, the *Minerva*, of Grenada, which we had hired to act as a convenient base for our expeditions on the mountain. The morning was spent in St. Pierre City, and on the sugar-cane plantations on the lower slopes of the mountain on the banks of the Rivière des Péres. The volcano was beautifully clear. Every ravine and furrow, every ridge and crag, on its gaunt naked surface stood out clearly in the sunlight. Thin clouds veiled the summit, but now and then the mist would lift sufficiently to show us the jagged broken cliff which overlooks the cleft. From the triangular fissure which serves as the crater hardly a whiff of steam was seen to rise, and the great heap of hot boulders which lies on the north side of and above this fissure could be perfectly made out. Small land-slides took place in it occasionally, and small jets of steam rose now and again from between the stones.

A little after mid-day large steam clouds began to rise, one every 10 or 20 minutes, with a low rumble. As they rose they expanded, becoming club-shaped and consisting of many globular rolling masses, constantly increasing in number and in size as they ascended in the air. They might be compared to a bunch of grapes, large and small, or to a gigantic cauliflower. When their upward velocity diminished they floated away to leeward, and fine ash rained down in a dense mist as they drifted over the western side of the mountain. They occasioned no anxiety in our minds, as we had found that the mountain was never long without exhibiting these discharges, and they were due merely to an escape of steam carrying with it fine dust. They rose, as a rule, to heights of 5000 or 6000 feet above the sea.

That afternoon as the sun was getting lower in the heavens and the details of ravine and spur showed a contrast of light and shadow which was absent at mid-day, we sailed along from St. Pierre to Précheur, intention obtaining a series of general photographs of the hill. The steam puffs continued, and, about 6 o'clock, as we were standing back across the bay of St. Pierre, they became more numerous, though not much larger in size. We ran down to Carbet, a village $1\frac{1}{2}$ miles south of St. Pierre, where there is a supply of excellent water and good anchorage. About half-past six it was obvious that the activity of the mountain was increasing. The cauliflower clouds were no longer distinct and separate, each following the other after an interval, but arose in such rapid succession that they were blended in a continuous emission. A thick cloud of steam streamed away before the wind so laden with dust that all the leeward side of the hill, and the sea for 6 miles from the shore, was covered with a dense pall of fine falling ash. The sun setting behind this cloud lost all its brightness, and became a

pale yellowish-green disc, easily observable with the naked eye. Darkness followed the short twilight of the tropics, but a 4 days' old moon shed sufficient light to enable us to see what was happening on the hill-side.

An Incandescent Avalanche.

Just before darkness closed in, we noticed a cloud which had in it something peculiar, hanging over the lip of the fissure. At first glance it resembled the globular cauliflower masses of steam. It was, however, darker in colour, and did not ascend in the air or float away, but retained its shape, and slowly got larger and larger. After observing it for a short time, we concluded that it was travelling straight down the hill towards us, expanding somewhat as it came, but not rising in the air, only rolling over the surface of the ground. It was so totally distinct in its behaviour from the ascending steam clouds that our attention was riveted on it, and we were not without apprehension as to its character. It seemed to take some time to reach the sea (several minutes at least), and as it rolled over the bay we could see that through it there played innumerable lightnings. We weighed anchor and hoisted the sails, and in a few minutes were slipping southward along the coast with a slight easterly wind and a favourable tide. We had, however, scarcely got under way when it became clear that an eruption was impending. As the darkness deepened, a dull red reflection was seen in the trade-wind cloud which covered the mountain summit. This became brighter and brighter, and soon we saw red-hot stones projected from the crater, bowling down the mountain slopes, and giving off glowing sparks. Suddenly the whole cloud was brightly illuminated, and the sailors cried, "the mountain bursts!" In an incredibly short space of time a red-hot avalanche swept down to the sea. We could not see it start from the crater owing to the intervening veil of cloud, but the lower parts of the mountain were clear, and the glowing cataract poured over them right down to the shores of the bay. It was dull red, with a billowy surface, reminding one of a snow avalanche. In it there were larger stones which stood out as streaks of bright red, tumbling down and emitting showers of sparks. In a few seconds it was over. A loud angry growl had burst from the mountain at the moment when this avalanche was launched from the crater. It is difficult to say how long an interval elapsed between the time when the great glare burst on the summit and the incandescent avalanche reached the sea. Possibly it occupied a couple of minutes: it could hardly have been more. Undoubtedly the velocity was terrific. Had any buildings stood in its path they would have been utterly wiped out, and no living creature could have survived that blast.

The Lightning Discharges.

Hardly had its red light faded when a rounded black cloud began to shape itself against the starlit sky, exactly where the avalanche had been. The pale moonlight shining on it showed us that it was globular, with a bulging surface, covered with rounded protuberant masses, which swelled and multiplied with a terrible energy. It rushed forward over the waters, directly towards us, boiling, and changing its form every instant. In its face there sparkled innumerable lightnings, short, and many of them horizontal. Especially at its base there was a continuous scintillation. The cloud itself was black as night, dense and solid, and the flickering lightnings gave it an indescribably venomous appearance. It moved with great velocity, and as it approached it got larger and larger, but retained its rounded form. It did not spread out laterally, neither did it rise into the air, but swept on over the sea in surging globular masses, coruscating with lightnings. When about a mile from us it was perceptibly slowing down. We then estimated that it was 2 miles broad and about 1 mile high. It began to change its form; fresh protuberances ceased to shoot out or grew but slowly. They were less globular, and the face of the cloud more nearly resembled a black curtain draped in folds. At the same time it became paler and more grey in colour, and for a time the surface shimmered in the moonlight like a piece of silk. The particles of ash were now settling down, and the white steam, freed from entangled dust, was beginning to rise in the air.

The cloud still travelled forward, but now was mostly steam, and rose from the surface of the sea, passing over our heads in a great tongue-shaped mass, which in a few minutes was directly above us. Then stones, some as large as a chestnut, began to

fall on the boat. They were followed by small pellets, which rattled on the deck like a shower of peas. In a minute or two fine grey ash, moist and clinging together in small globules, poured down upon us. After that for some time there was a rain of dry grey ashes. But the cloud had lost most of its solid matter, and as it shot forwards over our heads it left us in a stratum of clear pure air. When the fine ash began to fall there was a smell of sulphurous acid, but not very marked. There was no rain.

The volume of steam discharged must have been enormous, for the tongue-shaped cloud broadening as it passed southwards covered the whole sky except a thin rim on the extreme horizon. Dust fell on Fort de France and the whole south end of Martinique. The display of lightning was magnificent. It threaded the cloud in every direction in irregular branching lines. At the same time there was a continuous low rumble overhead.

What happened on Mont Pelée after this discharge cannot be definitely ascertained. For some hours afterwards there were brilliant lightnings and loud noises which we took for thunder. That night there was a heavy thunderstorm over the north-end of Martinique, and much of the lightning was atmospheric, but probably the eruption had something to do with it, and the noises may have been in part of volcanic origin.

Characteristics of the Eruptions.

There can be no doubt that the eruption we witnessed was a counterpart of that which destroyed St. Pierre. The mechanism of these discharges is obscure, and many interesting problems are involved. But we are convinced that the glowing avalanche consisted of hot sand and gases—principally steam; and when we passed the hill in R.M.S. *Wear* a few days later, we had, by the kindness of the captain, an excellent opportunity of making a close examination of the shore from the bridge of the steamboat. The south-west side of the hill along the course of the Rivière Seche was covered with a thin coating of freshly fallen fine grey ashes, which appeared to be thickest in the stream valleys. The water of the rivers flowing down this part of the hill was steaming hot. This was undoubtedly the material emitted from the crater on the night of the eruption. There was no lava. We saw no explosions of combustible gases, and nothing like a sheet of flame. We were agreed that the scintillations in the cloud were ordinary lightnings which shot from one part of its mass to another, and partly also struck the sea beneath.

The most peculiar feature of these eruptions is the avalanche of incandescent sand and the great black cloud which accompanies it. The preliminary stages of the eruption, which may occupy a few days or only a few hours, consist of outbursts of steam, fine dust and stones, and the discharge of the crater lakes as torrents of water or of mud. In them there is nothing unusual, but as soon as the throat of the crater is thoroughly cleared, and the climax of the eruption is reached, a mass of incandescent lava rises and wells over the lip of the crater in the form of an avalanche of red-hot dust. It is a lava blown to pieces by the expansion of the gases it contains. It rushes down the slopes of the hill, carrying with it a terrific blast, which mows down everything in its path. The mixture of dust and gas behaves in many ways like a fluid. The exact chemical composition of these gases remains unsettled. They apparently consist principally of steam and sulphurous acid. There are many reasons which make it unlikely that they contain much oxygen, and they do not support respiration.

THE PERSEID METEORIC SHOWER OF 1902.

THE display of Perseid meteors was fairly abundant this year, though somewhat marred, and only partially observed, in consequence of the unsettled weather which prevailed. In the west of England the first half of August proved an exceptionally cloudy period, and comparatively few observations could be secured. In the eastern counties atmospheric conditions appear to have been decidedly more favourable, for while at Bristol only meagre results could be gathered from skies wholly or partially veiled with clouds, observers in metropolitan suburbs reported clear weather and collected a plentiful harvest of meteor flights. At Hampstead Mr. G. M. Knight counted 500 meteors during the first fortnight of August. Between August 1 and 5, 167 were recorded, and on August 10, from

11h. 30m. to 15h. 15m., 239 were seen. The majority of them were Perseids of the usual swift, streak-leaving type, and there were minor showers in Cassiopeia, Andromeda, Cepheus and other regions. Mr. Knight has forwarded the writer some charts containing projections of his recorded paths, and the place of the Perseid radiant appeared to be indicated as under. The ephemeris positions given in the *Monthly Notices*, December, 1901, p. 169, are also added for comparison:—

1902.	Radiant.	No. of meteors.	Ephemeris.
August 1-3 ...	37° + 55°	12 ...	33°9' + 55°0'
„ 4-5 ...	40° + 55½°	26 ...	37°0' + 55°6'
„ 10 ...	44½° + 57°	43 ...	44°3' + 56°9'

The agreement is fairly good, though the places observed this year in the early part of August are somewhat east of the predicted centres. A certain allowance has, however, to be made for errors of observation.

At Bristol the writer watched for the Perseids on parts of the nights of August 2, 6, 10, 12 and 14, but clouds prevented anything like a thorough investigation of the progress of the display. The Perseids were fairly numerous, and shot from the radiant given below, but very few meteors were seen on August 6 and 14 owing to the clouds, so that the points of emanation on those nights were merely suspected:—

1902.	Radiant.	Ephemeris.
August 6 ...	39° + 57°	38°9' + 56°0'
10 ...	45° + 58½°	44°3' + 56°9'
12 ...	47° + 58½°	47°1' + 57°3'
14 ...	50° + 57°	50°0' + 57°7'

The year 1900 not having been a leap-year, the maximum was expected on either August 11 or 12. There was an unusually bright exhibition of these meteors on August 11, 1898. It seems that the maximum intensity was well defined this year, for “a magnificent shower of Perseids” is reported to have been witnessed at Odessa on Tuesday night, August 12. The chief radiating point is said to have been at an altitude of 45° or 50° in the north-east firmament. The latter position corresponds approximately with the normal place of the Perseid centre. But, unfortunately, the report mentions no details as to the number of meteors observed or the duration of the observations, and it is impossible, therefore, to form any exact conclusion as to the character of the display witnessed. It will probably be found, however, when particulars come to hand, that it represented nothing more than a tolerably plentiful return of the stream. There are no other descriptions favouring the inference that a strikingly brilliant shower was witnessed. In and since 1898 the Perseids appear to have been richer than usual, though it is extremely difficult to ascertain the relative strength of the shower from year to year owing to the variable conditions affecting the visibility of the meteors. W. F. DENNING.

THE ZOOLOGICAL SOCIETY'S NEW APE-HOUSE.

THE ordinary plan of keeping monkeys in zoological gardens is to house them in cages which, while closed in winter, can be opened to playing-places in the external air in summer. The objection to this course is that, though it gives the great advantage of fresh air, the monkeys emerging from a heated chamber into a cooler atmosphere are very liable to catch cold and suffer from pulmonary complaints. In the case of some of the harder Quadrumana (such as the Tcheli monkey of Manchuria and the Cape baboon), there can be no doubt that such animals will thrive best without artificial warmth of any kind beyond the protection of a dry roof, and may be kept in the open air all the year round. This plan, however, would hardly answer in the case of the anthropoid apes, which live in hot, moist climates and are accustomed all their lives to a high and uniform temperature. In constructing the new ape-house for the special accommodation of these animals, the Zoological Society has adopted the plan, which has been tried with some success on the continent, of separating the animals entirely from the evils of a changeable climate by an air-tight glass screen through which only they can be seen by the public. The